

USEFUL, EASY,
DIRECTIONS FOR SEAMEN,
WHO USE
HADLEY'S QUADRANT.
— *K* SHEWING, TO THE
MEANEST CAPACITY,

How to hold the Quadrant to take the Fore and the Back Observations of the Sun and of a Star; and the Meaning of the Observations.

How to examine whether the Index-glass, and the Fore and Back Horizon-glasses, stand in a right Posture; and how to set them right when they do not stand right.

The Meaning of what is called the Dip of the Horizon, or the Height of the Eye above the Water; and how to find it by the Quadrant.

The Meaning of what is called the Refraction of the Air, and how to prove it.

Many other very necessary Things, which every Seaman, who uses the Quadrant, should understand, if he be desirous of knowing the Meaning of what he is about.

A Book of this Sort has been much desired by some Seamen, and it may be very useful to many.

Whatever you have learned you should make it known; and, by doing so, you improve yourself, and you may do good to other People.

RINGELBERGIUS DE RATIONE STUDIÏ.

L O N D O N :

Printed for RICHARDSON and URQUHART, under the
Royal Exchange.

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TO ALL THOSE
MARINERS

Who desire to have such
EASY RULES
FOR USING
HADLEY'S QUADRANT,

That they may know the
MEANING OF WHAT THEY DO.

THIS small and cheap Book shews the Use of the Quadrant to the meanest Capacity.—This Book shews the Navigator the Meaning of what he is about—He will see the Nature of the Fore Observation, and of the Back Observation—This Book tells him how to hold the Quadrant in the Back and in Fore Observation—It tells him when the Sun is up, and when he begins to fall, in the Fore and in the Back Observation.—This Book shews him how to try the Index-glass, and both the Horizon-glasses, whether they stand in a right Posture, and how to set them right when they want it—It shews many other useful Things, as you will see in the Table of Contents.—The whole Book is wrote in such Words as are easily understood by any common Capacity. The chief Reason for putting out this Book was, to try to make that Knowledge, which the Almighty has blessed me with, useful to

Somebody ; for I am very sure, it is such Knowledge as many Seamen would be glad to have. If the Navigator carefully reads the Book throughout, he will be sure of finding useful Things which are not mentioned in any Book of Instructions put into a Quadrant-Box. When he finds more Words used than he thinks enough to shew the Meaning of what is there talked about, I beg he will kindly forgive me ; because, I heartily wish to be well understood by every Seamen who does use a Quadrant, or is desirous of doing so ; and there are many Men of this Sort who love to have Things made as easy to them as possible.

The Glasses belonging to the Quadrant are liable to be put out of their right Posture by the Warping of the Wood-work. Should either the Stroke of a Rope, or a Fall, put the Index-glass, or the Horizon glasses, out of their right Posture (which has happened, and may happen again) very dangerous must it be for that Vessel, if there be but that one Quadrant on Board : And in Vessels of 70 or 80 Tuns, very often there is no other Artist but the Master : If the Navigator of one of these Vessels should put his Index-glass out of its right Posture, in the latitude of about 49 degrees North, when he is making the English Channel, in the Winter, when the Days are short

short and stormy, the Vessel must be in great Distress; for she must then run by Guess in the Day, and lie by Night after Night. The Soundings are useful, but they ought not to be trusted to alone; and Soundings can not be well made in a great Sea; and if it blows hard from the southern Quarter (which it often does in the Winter) and there is a great Sea, to say nothing of the great Draught into St. George's Channel, the Vessel, in a short Run, may be twenty Miles or more to the northward of her dead Reckoning. Should she, in this Case, unfortunately be bold enough to make for the Channel in the Night, she may be taken up by Scilly Rocks, or, if happily she escapes them, she may be driven into and embayed in Bristol Channel. But had the Artist been able to new-place his Index-glass he then, trusting to his Observations, runs boldly up the Channel, Day and Night, to his Port.

Perhaps more need not be said to recommend the Book to those for whom it is written.

Frequently, a Work of great Utility, however well intended, however well executed, does not escape the Sarcasms of ostentatious Erudition and Envy. These humble Sheets open a capacious Field for a Display upon Poverty of Style, Tautologies, maimed Periods,

riods, awkward Shifts, with et ceteras : But such Invectives will avail little with the Unprejudiced, who consider the real Necessity of a Tract something like this. How far this Work performs what the Title-page promises, is submitted to the decision of the Impartial. Should its Utility conciliate their Patronage, the Hypocritic's Censure will as little affect me, as this Advice and Precept of Horace may influence him.

: certis Medium ac tolerabile Rebus
Rectè concedi——

Si quid novisti rectius istis,
Candidus imperti : Si non, his utere mecum.

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AN ACCOUNT OF
HADLEY'S QUADRANT;
AND
HOW TO USE IT.

CHAP. I.

THE parts of this noble and useful instrument, are,

The sides, sometimes called the limbs, AB, AY.

The arch, BC.

The braces, D, E, F. These strengthen the quadrant, and hinder it from warping much.

On the other side, or at the back of the quadrant, there is often a handle fastened to the braces, F and D.

The index, G.

The fore sight-vane, H.

The fore horizon-glass, I.

The back sight-vane, K.

The back horizon-glass, L.

The screens, or dark glasses, M.

The index-glass, N.

The scale called the Vernier, V. Because it was found out by Peter Vernier, a Frenchman.

To count the degrees and parts of a degree of the arch, BC.

360 degrees is the whole circle, 90 degrees is the quarter of 360, therefore those arches that have 90 degrees marked upon them are called Quadrants.

This arch is, in truth, no more than 45 degrees, the half of 90, and therefore half-a-degree is used for a whole degree; the reason of this, is, because you bring down the image of the sun thrown from the index glass upon the horizon glass; and learned men have found, that the image comes down in the heaven, two degrees when the index has moved only one degree upon the arch.

For this reason, half-a-degree upon the arch is called a whole degree, because it measures a whole degree in the heaven, and therefore the arch shews the sun's altitude truly.

Sixty miles make one sea degree; every degree upon the arch is divided into three parts, each part therefore goes for 20 miles—The whole arch BC is divided into two arches; the inner arch from Y to B; the outer arch from Y to C.

To count the degrees, and each 20 miles on the inner arch YB.

Begin at O, and go on to the left hand with 10, 20, and so on to 90, and the few degrees over 90.

To count the degrees, and each 20 miles on the outer arch YC.

Begin at O, and go on to the right hand towards C,

The

The arch shews the altitude for any degree, and for 40 and 20 miles; but it goes no lower than 20 miles. The Vernier shews every mile under 20 by this short rule, that line upon the Vernier which touches any line upon the arch is the miles under 20 which you seek for. [*See a rule at the bottom.*] The middle line of the Vernier is longer than the other lines upon it.

The figures stand thus.

10	15	long line	5	10
Left side of the Vernier			Right side of the Vernier	

Begin to count from the right side of the long line, and go on towards the right hand, thus, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Begin at 10 on the left side of the long line, and come on towards the long line, say 11, 12, 13, 14, 15, 16, 17, 18, 19, and the long stroke makes 20.

Some quadrants have their Verniers numbered another way; but this, I believe, is the most common way.

To count the miles, called also Minutes, on the Vernier's scale.

When you are looking for the miles upon the Vernier, hold the quadrant with the arch towards you, place your eye fully against the line on the Vernier that touches the line on the arch, and look almost strait down upon that part of the arch where the line on the Vernier seems to touch the line on the arch.

To use the Vernier upon the inner arch YB.

Move the index along the arch, till the long line upon the Vernier shews, upon the arch, something more than 24 degrees. Then,

To find the miles under 20.

1. Begin at the long line upon the Vernier, and carry your eye to the right, along the Vernier. Look for that line upon the Vernier that touches a line upon the arch; and, suppose it should be the seventh line upon the Vernier that touches a line upon the arch, the altitude is then 24 degrees and 7 miles.

2. Push the index a very little forwarder on the arch, and make the 10th line on the Vernier touch a line on the arch, then the altitude will be 24 degrees and 10 miles.

3. Push the index so far forward, that the long line of the Vernier may be about a hair's breadth, on the right side of the first line, past the 24th degree upon the arch: count from the long line, along the Vernier as before; you see that the right side of the Vernier, does not touch any line upon the arch; therefore begin at 10 on the left side of the Vernier, and come on towards the long line, and suppose the 14th line of the Vernier touches a line upon the arch, the altitude is then 24 degrees 14 miles.

4. Push the index farther forward, till the long line on the Vernier lies a little on the right of the second line, beyond the 24th degree. You see the long line of the Vernier has passed 24 degrees and 20 miles, and to find the miles upon the Vernier, you see the right side of the Vernier does
not

not touch any line upon the arch; therefore begin at 10 on the left side of the Vernier, and come on towards the long line, and suppose the 16th line of the vernier touches a line upon the arch; these 16 miles must be added to the 24 degrees and 20 miles, which the long line of the Vernier passed by on the arch; so that the altitude is 24 degrees and 36 miles.

Try these 4 examples 2 or 3 times, and you will then be able quickly to read off the degrees and miles, shewn by the Vernier on any part of the inner arch.

To use the Vernier upon the outer arch YC.

You begin at O, and go on to the right, when you count the degrees, and each 20 miles upon this arch.

There are two ways of getting from the Vernier the miles under 20.

First Way.

Seek for the miles upon the Vernier in the same way you did on the inner arch; subtract them from 20, and the miles that remain are what you want; and they are to be added to what the long line upon the Vernier shows you upon the outer arch.

E X A M P L E.

Suppose the long line upon the Vernier has passed one degree upon the outer arch, and lays about a hair's breadth on the left side of the first 20th mile-line, beyond that one degree. You look along the Vernier as you do on the inner arch, and you find that the fourth mile cuts a line upon the arch. Now from 20 subtract 4, there remain 16 to be
added

added to 1 degree; so that the Vernier shewed 1 degree and 16 miles.

The second way of getting the miles under 20 from the Vernier, when it is upon the outer arch.

The Vernier for the inner arch is, you know, numbered in this manner, 10 15 | 5 10. But if you read the numbers on the Vernier in the backward way, thus, 10 5 | 15 10, which is only changing the places of 5 and 15. Then you see you must begin to count from the left side of the long line upon the Vernier, and go on to the left to 10; and for the miles above 10, begin at 10 on the right side of the long line, and come on to the left hand, till you come to the long line, or 20th mile.

EXAMPLE.

Let the long line upon the Vernier almost touch the first twenty mile-line beyond the first degree, as in the last example. Then begin on the left side of the long line upon the Vernier, look along the left side of the Vernier, you see there is not one line on the left of the long line, that touches a line on the arch. Look on the right side beginning at 10, and come on towards the long line, you see the 16th line on the Vernier touches a line upon the arch. So that the Vernier shews 1 degree and 16 miles, as in the above example.

At the bottom of the index, a piece of brass turns up against the back of the arch; in this piece of brass there is a screw to fasten the Vernier upon any line on the arch.

To get a nice observation of the sun's altitude, some quadrants have a fine screw fixed just below the Vernier, to move the Vernier, very slowly backwards

backwards and forwards on the arch. By this slow movement, the image of the sun may be made to brush the horizon exactly.

The index-glass is quicksilvered on one side; the middle part of the glass is put right against the center of the quadrant. This center is that dot on the left side of the letter N. [*See the figure of the quadrant.*] The use of this glass is to receive the image of the sun, and to cast this image on the horizon-glasses.

The fore horizon-glass has only its lower part quicksilvered; the upper part is left clear. The use of this glass is to receive the image of the sun cast from the index-glass, upon the quicksilvered part, when the sun is in a cloud, but the clear part is to receive the sun's image from the index-glass, when the sun shines bright. The upper part of this glass is left clear, chiefly for the sake of seeing the horizon through it.

The back horizon-glass is quicksilvered both at the top and bottom, and it has a clear slit across the middle. The use of this glass is to take the image of the sun, and the image of the horizon, behind you, cast from the index-glass. Instead of a clear slit in the middle of the glass to see the horizon, it might be better if the upper part was all clear as in the fore horizon-glass.

The red glasses, called also the Screens, are now in the upper hole at 1. [*See the figure of the quadrant.*] for the fore observation. Put them in the lower hole, at 2, for the back observation. One of these glasses is of a deeper red than the other. The use of these glasses is to take off the brightness

ness of the sun ; for these glassess being put between the index-glass and the horizon-glass, and the image of the sun passing from the index-glass, through these red glassess, to the horizon-glass ; these red glassess, I say, make the sun's image upon the horizon-glass to look of a dark red colour. At this red image you may look without hurting your eye.

The sight vanes stand directly upright upon the face, or upper side of the quadrant.

The fore sight-vane has two holes. The upper hole is right against the middle of the clear part of the fore horizon-glass ; the lower hole is right against the edge of the quicksilvered part. The upper hole is to be used with the clear part of the horizon-glass, when the sun is very bright. The lower hole to be used with the quicksilvered part of the horizon glass, when the sun is faintly seen through a cloud.

The back sight-vane has but one hole, it is over against the clear slit in the back horizon-glass.

C H A P. II.

To see whether the fore Horizon-glass stands right, to agree with the degrees and minutes upon the arch. How to set it right, and then the Vernier will shew the true observed altitude upon the arch.

AT the back of the quadrant, behind the fore horizon-glass, there is a round piece of brass, that has a short screw through the middle of it, between two upright pieces of brass. The round

round piece is called the handle for altering the fore horizon-glass; because, if you slacken the long screw, just above the handle, the handle will then move about that screw which goes through the middle of the handle, and will alter the fore horizon-glass on the face of the quadrant. You see there is a handle and screw just below, belonging to the back horizon-glass.

To make the fore horizon-glass agree with the degrees and minutes upon the arch.

Move the index, till the long line upon the Vernier touches, exactly, O, on the arch; loosen the long screw, just above the handle belonging to the fore horizon-glass.

To hold the Quadrant.

If your quadrant has no handle, to hold it with your right hand; then you may hold it thus. — Put your left hand under the swelling part, where the back horizon-glass and the back sight stands; let the swelling part rest upon the fore-finger; stretch your thumb athwart that side of the quadrant, and put your thumb up the edge towards the handle of the fore horizon-glass; the end of your fore-finger will place itself somewhere near the handle of the back horizon-glass; turn the face of the quadrant towards the left arm; hold the quadrant upright, with the arch downwards; let the end of the arch rest against your stomach; stoop a little; look through the right hole in the sight-vane; take notice whether the image of the horizon, which you see in the silvered part of the horizon-glass, joins in the same strait line with the horizon, which you see through the clear part of the horizon-glass; if it does not join in the same

C

line,

line, so as to make one strait line, turn the handle of the fore horizon-glass, at the back of the quadrant, gently backwards and forwards, till you bring the image of the horizon in the silvered part of the glass, to be in the same strait line with the horizon, you see through the clear part of the glass; then fasten the long screw just above the handle, and the fore horizon-glass is then truly set for the observation you are going to make. The horizon-glass is liable to alter every day, so it will be best to examine it every day before you begin to observe the sun's altitude.

To take the Sun's altitude by the fore Observation.

In clear weather, observe the altitude of the sun's lower edge; in foggy weather, and you cannot plainly see the lower edge, observe the altitude of the sun's center.

The navigator may find it profitable to observe the following directions about using the dark glasses, and the sight holes, in the vane, according to the brightness of the sun.

1. When the sun is behind a cloud, and you can not plainly see his body with the naked eye; use only the lighter coloured dark glass, look thro' the lower hole of the vane, upon the silvered part of the horizon-glass.

2. When you can see the sun very plainly thro' the cloud, use the lighter coloured dark glass: look through the upper hole of the vane, upon the clear part of the horizon-glass.

3. When the sun shines bright, use the darker of the red glasses; perhaps you may want both the

the glasses; look through the upper sight hole of the vane, upon the clear part of the horizon-glass.

The fore Observation is this.

You face the sun, and you measure the arch in the heaven, between the lower edge of the sun, and that part of the horizon right under the lower edge of the sun. Put the long line on the Vernier to O on the arch; fix the red glasses into the hole above the fore horizon-glass, turn down one or both of them, according to the brightness of the sun, as in the three rules before mentioned. If the quadrant has no handle at the back to hold it with your right hand, take the quadrant in your left hand, hold it upright, and the arch downward, just in the same way as when you set the fore horizon-glass; turn yourself towards the sun, and if the sun shines bright (according to the third rule about the brightness of the sun) put your eye close to the upper sight hole, and look through the middle of the clear part of the fore horizon-glass, for that part of the horizon right under the sun. Put your fore finger and thumb of your right hand to the bottom of the index, to move the index from you, till you see the red image of the sun come down towards the horizon. When the lower edge of the sun seems very near the horizon, bend your body upon your hips to the right, and then to the left; and you will see the image of the sun make the arch of a circle. Then push the index forward (or turn the fine screw, fixed below the Vernier for a nice observation, if you have a screw) then bend your body upon your hips as before, and move the index, till, by this swaying upon your hips, you make the lower edge of the sun's image just brush the horizon. Then

stop the index, for the observation is well made.
And,

*To get the Sun's altitude when he is on the meridian,
which is the thing used to find the latitude in.*

Keep on observing, and all the while the sun rises you will see the image of its lower edge, upon the horizon-glass, to be above the horizon; then move the index gently forward to bring the sun down to the horizon, and sway your body upon your hips to let the sun brush the horizon. Thus go on observing till the sun be at the highest. This greatest altitude is called the meridian altitude. When the sun is on the meridian, it will seem to rest a few minutes before it begins to fall. When the sun begins to fall, you will see its lower edge below the horizon, and it will seem to come upon the water towards you.

*To have the true meridian altitude of the center of
the Sun.*

1. Count the degrees and minutes as before directed, and this is the observed meridian-altitude of the sun's lower edge.

2. Add the dip of the horizon of the sea to the refraction of the air. [See the tables in pages 28, 31.] The meaning of these two things are shewn in chap. 4.

3. Subtract the sum of the dip and refraction from the observed altitude, and what remains will be the true meridian-altitude of the sun's lower edge. To this remainder add 16 miles (for half the sun's breadth) and you will have the true meridian-altitude of the sun's center. But when you observe

observe the altitude of the sun's center, the 16 miles are not to be added.

EXAMPLE.

Suppose you observed the meridian-altitude of the sun's lower edge 21 degrees 15 miles, when your eye was 12 feet higher than the water.

	Miles.
In page 28, for 12 feet high, is	3
In page 31, for 21 degrees of altitude,	2
The sum of the dip and refraction	5
Then,	

	deg. m.
From the observed altitude of the lower edge,	21 15
Subtract the sum of the dip and refraction,	5
Remains the true altitude of the sun's lower edge,	21 10
Add for half the sun's breadth,	16
This sum is the true meridian-altitude of the sun's center,	21 26

C H A P. III.

The back Observation is, when you turn your back to the Sun.

IN the back horizon-glass you see every thing upside down; the water appears above you, and the sky under your feet. The small distance, in some quadrants, between the index-glass and the back horizon-glass, will not let you wear your hat, or have any thing high upon your head while you are observing.

To see whether the back Horizon-glass stands right to agree with the degrees and minutes upon the arch. How to set it right, and then the Vernier will shew the true observed altitude upon the arch.

Move the index on the outer arch (the right hand of O) till the long line upon the Vernier touches, exactly, as many miles as is twice the dip of the horizon. Thus suppose your eye is 12 feet higher than the water; 12 feet by the table, page 28, gives 3 miles, and twice 3 miles (that is twice the dip) is 6 miles. Now, loosen the long screw just above the handle, belonging to the back horizon-glass; and,

To hold the Quadrant.

If the quadrant has no handle, to hold it with your left hand, then you may hold it thus. Put your right hand under the back horizon-glass, and turn the back of the quadrant towards your left arm; put the right thumb under the swelling part, upon which the back sight vane stands; let the

the first joint of your fore-finger bear against the edge of the quadrant, opposite to your thumb; put the middle or longest finger just under the handle of the back horizon-glass, then the other two fingers will lay upon the cross-brace D. Hold the quadrant upright, with the arch downward; let the end of the arch rest against your breast; stoop a little; look through the hole in the back sight-vane, and if the horizon, which you see through the clear slit in the back horizon-glass, joins in the same strait line with the image of the horizon behind you, which you see in the silvered part of the horizon-glass, then the glass needs no altering; but, if the two horizons do not join so as to make one strait line, with your left hand turn the handle belonging to the back horizon-glass, till you bring the image of the horizon in the silvered part of the glass, to make one strait line with the horizon, which you see through the clear slit. Then fasten the long screw just above the handle, and the back horizon-glass is truly set for the observation you are going to make.

Take notice, if the horizon which you observe through the clear slit of the glass, and the image of the horizon which you see in the silvered part, can not be made to touch all along, and to become one strait line; but, instead of that, they cross each other, you do not hold the quadrant upright, therefore you must move the quadrant till both the horizons look parallel, then, turn the handle, and you will bring both horizons to make a strait line.

Note, To know what is meant by the word Parallel, look at figure 2. The line KZ is parallel to the line HO. This means, that the line KZ keeps

keeps the same distance from the line HO, all the way, or from end to end.

To take the Sun's altitude by the back Observation.

In this observation you see every thing upside down, the water above you, and the sky under your feet; the upper edge of the sun now seems to be the lower edge.

The back Observation is this.

You turn your back to the sun, and you bring up what seems to you to be the lower edge of the sun, from under your feet, to brush the horizon before you. By doing so, you measure the arch between the image of the upper edge of the sun under your feet, and the horizon that is before you. Put the red glasses into the lower hole, and, according to the brightness of the sun, use one or both glasses, as is mentioned in taking the fore observation. Put the long line upon the Vernier to O upon the arch; hold the quadrant as it is directed for setting right the back horizon-glass; turn your back to the sun; bend your body a little forward; look through the clear slit in the horizon-glass; move your body gently to the right and left till you find the red image of the sun upon the horizon-glass; then raise yourself, and with the left hand move the index gently towards you, till you bring the red image of the sun up to the horizon, which you see through the clear slit of the glass, and make (what now you see to be) the lower edge of the sun to stand upon the horizon. Keep the quadrant steady in your hands, and sway your body to the right and left, and if
the

the sun's lower edge does just brush the horizon, your observation is well made.

To get the Meridian Altitude.

Keep on observing, and all the while the sun rises, you will see the image (of what you now call the sun's lower edge,) keep dropping below the horizon; then move the index towards you, to bring up the lower edge to stand upon the horizon, and make the lower edge brush the horizon as before. When the sun begins to fall, this edge, you now call the lower edge, will shew itself above the horizon.

To have the true Meridian Altitude of the Sun's Center.

1st, Count the degrees and miles as before directed, and this is the observed meridian-altitude of the sun's upper edge.

2dly, Add the dip to the altitude. [See the meaning for doing this in Chap. IV.]

3dly, Subtract the refraction from this sum, and there will remain the true meridian-altitude of the sun's upper edge from the horizon behind you.

4thly, From this true meridian-altitude of the sun's upper edge, subtract 16 miles (half the sun's breadth) this remainder is the true meridian-altitude of the sun's center above the true horizon under the sun.

The reason of subtracting half the sun's breadth is, because the upper edge of the sun, by the back observation, shews itself to be the lower edge.

E X A M P L E.

Suppose you observed the meridional-altitude of the sun's lower edge, 21 degrees 41. miles, when your eye was 12 feet higher than the water.

	D. M.
The meridional-altitude observed, —	21 41
Add the dip for 12 feet —	3
From this sum —	21 44
Subtract the refraction for 21 degrees —	2
There remains the true meridian-altitude of the sun's upper edge, —	21 42
Subtract for half the sun's breadth, —	16
This is the true meridian-altitude of the sun's center above the true horizon } under the sun, —	21 26

C H A P. IV.

MANY seamen do not make allowance, either for the dip of the horizon of the sea, or for the refraction of the air, which perhaps they would do, if the reason of each thing were shewn them by a figure in the books of navigation that are commonly used, or in every book of instructions given with the quadrant. These two allowances are so necessary to be made, that the latitude of the ship cannot be had truly without doing so.

To understand what is meant by the dip of the Horizon of the Sea. [See Fig. 2.]

Let the arch NMEY be called a part of the surface of the sea, for the earth is round like an apple, or rather like an orange. When your eye is at the water's edge, as at E, your true horizon is the line HO; but if your eye is above the sea, suppose at L, and you look strait forward to K, your true horizon will then be the line KLZ; because this line KLZ is parallel to the true horizon HO, when your eye was at the water's edge; but if you look to where the sky and water seem to touch, as suppose at M, the line LM is called the visible horizon; the arch of the sky KM is called the dip of the horizon of the sea, because the visible horizon, the line LM (where the sky and water seem to meet at M, when your eye is at L) I say this visible horizon LM, dips or falls below the true horizon KL. Now,

When you observe the sun's altitude by the fore observation, you bring the image of the lower edge of the sun down to the visible horizon, that is, down to M (where the sky and water seem to meet) and your quadrant gives you the sun's altitude, or the length of the arch from M up to the sun at B; and this arch from M up to B, is too much by all the length of the arch MK. Thus you see very plainly, that when your eye is at any height above the water, you bring down the sun's image below the true horizon, and by doing this, the quadrant shews you more altitude than the truth; therefore that altitude must be made less by as much as the visible horizon LM (meaning the point M) is below the true horizon LK, or the point K. How much this dip is you find in the

tables underneath, against such number of feet as your eye is higher than the water.

When the eye is higher than the water's edge, it can not mark out a true horizon in the sky. Suppose such as the point K, when the eye is at L; to this point K, the image of the sun ought to be brought down, and no lower. For this reason, learned men have made tables, shewing you how many miles the visible horizon LM, dips below the true horizon LK, when your eye is at any height above the top of the water, from 1 foot high to 40 feet.

A Table of the Dip of the Visible Horizon of the Sea below the true Horizon, for any Height of the Eye above the Sea, from 1 Foot to 40 Feet.

Height of the Eye in Feet.	Dip of the visible Horizon in Miles.
1	1
3	2
8	3
15	4
24	5
39	6
40	6

Note, See by Chap. 7, how to find the dip by the quadrant, let your eye be what height it will above the top of the water.

To use this Table.

The dip for 2 feet is 1 mile, the same as for 1 foot. So the dip for 4, 5, 6, 7 feet is 2 miles, the same as for 3 feet, and so on.

To

*To understand what is meant by the Refraction of
the Air.*

The refraction of the air causes the sun to appear higher in the heaven than it truly is. Learned men say, that the air, which is all round the earth, reaches 44 miles above the earth. When a beam of light, supposed from the sun, strikes upon the air (which may be justly called a very thin water) the beam is refracted, (that is, the beam is turned out of its first course from the sun) more if the sun be near the horizon, but less and less the higher the sun is above the horizon. The air, by thus turning the sun's beams out of their strait course towards the earth, causes the sun to appear higher than what the sun is. [*Look at fig. 3.*] This figure means to shew a part of the earth BMK, and a man standing at M, the strokes above the arch are to shew the air. The line S, t, means a beam of light, and when it strikes upon air at t, instead of going on a strait course from the sun, through the air, as StZ, the air causes the ray to bend at t, toward the earth, that is to E, the eye of the man at M; and he looking strait forward, as E, t, Y, he thinks he sees the sun at Y, which you see is higher in the heaven than the sun truly is. This thing, perhaps, may seem very strange to some persons, therefore, if any one will make the following easy trial, he will find it to be true. We breathe air, and this air is proved to be water by any person's breathing strongly five or six times against a looking-glass. Put a bason in the sun, and hold a stick, sharpened at one end, where the shadow of the rim or edge of the bason falls on the bottom of the bason; then fill the bason with water, and the shadow of the rim will fall more towards that

that side of the bason next to the rim, than it did when the bason was empty. This plainly proves, that as soon as the rays of light touch the top of the water in the bason, the rays are bent downwards into the water. But now pour the water out of the bason; set down the bason, and put a piece of money into it. [*See the fig. 4, ZE*] Then go from the bason to S, till the edge of the bason t , just hides the money from your sight; keep your head steady while somebody fills the bason gently with water; as he fills it, you will see more and more of the piece of money, which will come all in sight when the bason is full; and the money will shew as if lifted up as high as U, because the beam of light S, t , Z, coming from the eye at S, was strait while the bason was empty; but, now the ray S, t , Z, is bent at the top of the water at t , and instead of going on strait from t to Z, it is turned, and goes on strait to E, and so it makes a traverse of two courses from the eye at S; first course is St, the second course tE , instead of a single course or strait line S, t , Z. You remember, that when you strike at dolphins from the spritsail yard, you dart the harpoon nearer the ship's stem than the fish seem to swim. Now while you read the following comparison look at figure 3, and figure 4, and you will, plainly, see, that the air causes the sun to appear higher than it truly is.

Call the bason (*fig. 4.*) a large tub, and call the water in the bason air; suppose the man's eye at E in the air; call S (*fig. 4.*) the sun instead of your own eye. Then the man at E looking along the line E, t , will see the sun at Y, which place Y is higher above the horizon than S, the true place of the sun.

I beg leave to say a few more words. Suppose one man in the bow of a boat, a float in 4 or 5 feet water,

water, and his eye at the top of the stem; and suppose another man about half-a-boat's length a-head, and his head just under water, and to point a stick out of the water to the top of the boat's stem; the man in the boat would find that the end of the stick would be pointed higher than his eye, that is, higher than the top of the stem. This is so plain and easy a proof, that more need not be said.

A Table of Refraction of the Air to different Degrees of Altitude of the Sun, Moon and Stars.

Altitude observed.		Refraction.	Altitude observed.		Refraction.
deg.	miles.	miles.	deg.	miles.	miles.
0	5	32	5	20	9
0	10	31	6		8
0	20	30	7		7
0	40	27	8		6
0	50	26	9	40	5
1		24	11	45	4
2		19	15	30	3
3		15	21		2
4		12	33		1
5		10	63		0

The Use of this Table.

The refraction for 6 miles, for 7 miles, for 8 miles, for 9 miles altitude is 32 miles, the same as for 5 miles of the altitude. The refraction for 22 degrees, 23 degrees, and so on to 32 degrees, is 2 miles, the same as for 21 degrees.

The

C H A P. V.

The meaning of the Fore and the Back Observations.

The Fore Observation is this. You face the sun, and you measure the arch in the heaven between the lower edge of the sun, and that part of the horizon right under the sun. Now [look at fig. 2.] suppose your eye at L, you bring the image of the lower edge of the sun, as B, down to M, the visible horizon, and thus you measure the arch BM. But this arch BM is too much by the arch MK, the dip; for the sun should be brought no lower than the point K, which point is the true horizon. For this reason the dip is subtracted from the altitude. Again,

You bring down the sun's lower edge; but it is the sun's center, or middle C, which ought to be brought down; because the tables of the sun's declination are made for the sun's center. For this reason you add to the altitude of the sun's lower edge, half the sun's breadth, BC, 16 miles, to get the altitude of the center.

The Back Observation is this.

The glasses, by this Observation, shew the image of the upper edge of the sun as much below the true horizon before you, as the upper edge is above the true horizon behind you. [look at fig. 2.] Suppose your eye at L, with your back towards the sun, then the image of the upper edge of the sun, D, will be seen at X, under the horizon before you; therefore ZX is the distance of the image of the sun's upper edge from the true horizon; and learned men have proved, that this arch ZX measures just as much as the arch KD, and KD is the distance

distance of the sun's upper edge from the true horizon behind you. Now,

When you take the observation, you bring up the point X (which seems now to be the lower edge of the sun) to stand at Y, upon the visible horizon, before you, and so you measure the arch XY only. But the sun you know ought to have been brought up to Z, the point of the true horizon. But as this can not be done, the upper edge X (which seems the lower edge) is brought to Y, and then the dip YZ is added to this arch XY, shewn by the quadrant, and this gives you the arch XZ, just the same number of degrees and miles, as if you had found the true altitude by the fore observation.

To take the Altitude of a Star by the Fore Observation.

Turn back the screens, set the Vernier at O on the arch, put your eye close to the hole of the fore sight-vane, look directly at the star, and see it through the clear part of the fore horizon-glass, and see the star's image, at the same time, in the silvered part of the glass; move the index a little forward to part the image on the silvered part of the glass, from the star seen through the clear part; keep sight of the star's image on the silvered part as you move the index from you, and, at the same time, keep lowering the arch as the star comes down, till you have brought the star down to the horizon, which you see through the clear part of the glass, the Vernier shews the altitude. Be sure to keep in sight the star on the silvered part of the glass, till you have brought it to the horizon; if you do not, you may use some other star instead of that you design to take,

Note,

Note, Stars have no breadth, for this reason; subtract the sum of the dip and of the refraction, from the observed altitude, and you have the true altitude.

E X A M P L E.

Suppose you observed the altitude of the virgin's spike, 28 degrees 30 miles, when your eye was 15 feet higher than the water.

Dip 15 feet,	—	M.
Refraction for 28 degrees,	—	4
	—	2
	—	6

		Deg. M.
From the observed altitude	—	28 30
Subtract dip and refraction	—	6
Remains the true altitude	—	28 24

The altitude of a bright star can not very much be trusted to, except when the horizon is enlightened by the moon, or in fine summer nights, by a good twilight, then, indeed, the altitude of a star may be taken pretty exactly.

To take the Altitude of a Star by the Back Observation.

To do this the horizon ought to appear very plain. There are two ways of making this observation.

1st,

1st, To bring the star to the horizon, when the star is faint and the horizon bright. Some persons think the next way better; that is,

2^{dly}, To bring the horizon to the star.

To bring the Star to the Horizon.

You ought to know, nearly, how much altitude the star will have; if you do not know, you may be troubled to find the image of the star on the silvered part of the glass.

Set the Vernier to what you think the altitude will be, hold the quadrant upright, turn your back towards the star, and look through the clear slit of the horizon-glass to that part of the horizon opposite to the star; when you see the star's image on the silvered part, move the index to make the star touch the horizon.

To bring the Horizon to the Star.

Put the long line on the Vernier to O on the arch, look through the back horizon-vane, and through the clear slit in the back horizon-glass, and find the star; then move the index till, in the silvered part of the glass, you see the image of the horizon, which is behind you, to meet the star, the index then shews the observed altitude.

To get the true Altitude.

Subtract the refraction from the observed altitude, to the remainder add the dip; this sum is the true altitude.

E X A M P L E.

Suppose you observed the altitude of the virgins's ipeke 28 degrees 22 miles, when your eye was 15 feet higher than the water.

	Deg. M.
Altitude observed	28 22
Subtract the refraction for 28 degrees	2
	28 20
Add the dip for 15 feet	4
	28 24
This sum is the true altitude	

It may, perhaps, be thought that I ought to give directions for finding the index error by the fore and back observations; but as making the horizon-glasses agree with the degrees and miles upon the arch answers the same end; and to do this exactly, there are plain directions in the fore and back observations; I take no notice of finding the index error, being desirous of saying nothing more than what is really necessary to shew the nature of the fore and back observation.

C H A P VI.

BEFORE any thing is said about examining and new-placing the glasses, it is necessary to shew the use of the screws belonging to the glasses.

The Index Glass,

Is put into a brass frame, and this frame, with the glass slides, into the outer frame; the two little screws,

screws, *a*, *b*, [See fig. 5.] behind the outer frame are to drive the inner frame and glass tight or taut against the outer frame, that the glass may not wabble; the great screw, *A*, fastens the glass-frame upon the index, and it serves also to make the index-glass lean either backwards or forwards, to set it upright. When you turn the little screw, *c*, it pushes against the under plate of brass on the index, and makes the lap (the piece *d*, *n*, *o*,) rise hard against the great screw *A*, that it may steady the whole glass frame; but sometimes the index-glass [IG] [See fig. 6.] is fastened by two screws, *B*, *B*, to a round plate of brass, that rests upon two stumps (or short pins of brass) one stump under one end of the index-glass, and the other stump under the other end of the glass. The two screws *b*, *c*, fastens this round plate (which is called an adjusting plate) that bears the index-glass upon these two stumps. If you unscrew the screw, *b*, and screw up the screw, *c*, you will make the brass plate, and the index-glass with the brass plate to lean towards *c*; so if you unscrew the screw, *c*, and screw up the screw at *b*, you will make the plate and index-glass lean towards *b*.

Note, Both the horizon-glasses are put upon adjusting plates, and these plates have screws just the same, and the screws are to be worked in the same manner when the horizon-glasses are to be set upright, as you do when you set the index-glass upright.

To set the Index-Glass upright upon the Face of the Quadrant.

A fall, or some other accident, may put this glass out of the right posture; if no other thing happens, the warping of the wood-work will surely

ly do it; for this reason you should now and then examine the index-glass.

The following easy way the navigator may safely trust to; because index-glasses, that have been set by a very nice method, have been tried this way, and so very little difference has been found; that it cannot be of the least hurt to the navigator to use this way.

Pins, pasteboard, or the cover of a book, a piece of deal, a saw, a plane, compasses and ink, are on board almost every vessel, and in one hour's time a set of tools may be made proper for the business. Although this way is mentioned chiefly for a time of distress, yet, it will do at any time; but a mathematical instrument-maker can soon let the navigator have something for the purpose at a reasonable price, that will give the navigator no trouble to keep in order,

To make a Square. [See fig. 7.]

Take a bit of smooth pasteboard, about three inches long and three inches broad; within about half an inch from any side draw a strait line, as the line AB; open the compasses about one inch, and put one foot at B, about half an inch from the side, and put down the other foot any where, suppose at C; keep that foot fast in C, and sweep as much of a circle as you can.

Now from E, where the circle touches the line, draw a strait line thro' C, to touch the circle again in D ——— Then draw a strait line from D to B, where the circle again touches the line AB. ——— Then, with a very sharp knife, or with a good pair of scissars, cut strait through the lines AB and BD, leaving the corner exactly true, where the two lines AB and DB touch each other.

Then,

Then plane smooth, on every side, a piece of deal about a foot long, one inch broad, and half an inch thick.——With a saw (the finer it is the better) cut off two pieces, each piece about one inch long.——Let the saw come strait through, that the side of each piece may be as upright as possible, with the bottom; so that, when the pieces are set together on a level place, the two upright sides may truly touch each other.—Mark these sides to know them again.

Now cut a piece of pasteboard something more than one inch long, and one inch broad.——Black with ink one side of it.——When the ink is dry, make the pasteboard as flat as you can.——By the help of your square, draw a line strait down about the middle of the marked side of one piece of wood. [*See fig. 8.*]——Take a strait pin, about one inch long, and stick it into the top of that piece, as near the edge as you can, where the line drawn up the side touches the top.——Set the pin upright by the help of your square, by putting the piece of wood upon a level place, and then put your square on one side of the line, which is drawn up the side of the piece of wood; then put your square on the other side of the line; then turn the piece to put your square to the front of the piece.——When you have set the pin upright, mark the side of your square even with the middle of the pin's head.——Then cut asunder two pins, and with these tack the blacked piece of pasteboard upon the marked side of the other piece of wood, the black side of the pasteboard to be outwards or towards you. [*See fig. 9.*]——This thing you may call a sight-vane.——Now set this sight-vane upon a level place, put down your square, and with a pin mark upon your vane, the same height of the middle of the

the pin's head as you have upon the square. —

Through this mark in the vane, make a hole with a pin, about the width of the upright pin's head, and on the white side of the vane make a fine black stroke with a pen and ink round the sight-hole.

—— With these two instruments the index-glass may be set truly. — But before you begin to do that, see if the index-glass be tight in the frame; if you find it loose, screw up those little brass screws, *a*, *b*, at the back of the index-glass, but do not screw them too hard, for fear you should break or bend the glass.

Now, take the fore sight-vane clear off the quadrant, to let the index go over that place. — Lay the quadrant upon a table, where you have a good light, either on the right or left hand. — Put the sight-vane [*fig. 9.*] at 90 degrees on the arch, and set the piece of wood, with the upright pin [*fig. 8.*] on the left side of the quadrant, and very near the index, but not upon the index. — Let the pin be in the wake of the middle of the index-glass. — Move the index clear off the arch, put your right hand gently under the index, and let the weight of the index rest upon your hand, and move the index till the middle of the index-glass is right athwart the hole of the sight-vane. — Put your eye to the sight-hole, move the index a little backwards and forwards, to see whether the head of the pin will cover the image of the sight-hole on the inner or white side of the pasteboard; which image of the sight-hole you will see in the index-glass. If the head of the pin does cover the image of the sight-hole the index-glass is upright.

But, if you see the image of any part of the sight-hole above the pin's head, the index-glass leans forward or towards you. — Then, if your
index-

index-glass is not placed upon an adjusting plate, but has only one great screw [See A. fig. 5.] and the pushing screw *c*.——Slacken the pushing screw *c*, and screw down the great screw A.——Look again, and move the index backwards and forwards a little, and see whether the head of the pin covers the image of the sight-hole, which you see in the index-glass, and if it does cover it, gently turn the pushing screw, till you find the end of it bears upon the plate underneath.

If you see the image of any part of the sight-hole in the index-glass, below the pin's head, then the index-glass leans backwards.——

Loosen the great screw A, and turn the pushing screw *c*, till you find it has forced up the lap *d*, *n*, *o*, [See fig. 5.] to bear against the head of the great screw A.——Then look again, move the index backwards and forwards a little, and if the head of the pin covers the image of the sight-hole, which you see in the index-glass, then gently turn the pushing screw *c*, till you find the end of it bears upon the plate underneath.

If the index-glass is fixed on an adjusting plate.

——When the index-glass leans towards the arch.——Slack the screw *b*, [See fig. 6.] which is before the index-glass, and, gently, screw the screw at *c*, behind the index-glass.

When the index-glass leans backwards, or towards the screw *c*, slack the screw *c*, which is behind the index-glass, and gently screw the screw at *b*, which is before the index-glass.

Remember to place the sight-vane about the 45th degree or middle of the arch, and the upright pin directly over against it, close to the index, but not upon the index.——Then move the index backwards and forwards a little, and see whether

F the

the pin's head covers the image of the sight-hole in the index-glass.——In the same manner try the index-glass, by putting the sight-vane upon O upon the arch.——And if the face of the quadrant is quite flat, the pin's head will cover the image of the sight-hole in the index-glass, put the sight-vane upon any part of the arch you please.——But a very great exactness is not wanted.

Be careful to slack one screw before you screw up the other screw, that either screws down, or that pushes against the screw you slacken.——Leave all your screws tight, so that they may draw to keep each other steady.

Both the horizon-glasses are put upon adjusting plates, and they have screws in the same manner as the index-glass has when it is fixed on an adjusting plate.——Therefore, when these glasses are to be set upright, you must work the screws in the same manner,

To set the Fore Horizon-glass upright upon the Face of the Quadrant.

This is done to make it stand parallel to the index-glass. It ought always to be exactly parallel to the index-glass; then you may have a good observation, if the index-glass does not stand quite upright upon the face of the quadrant.

Bring the long line upon the Vernier to lay upon O, upon the arch; hold the face of the quadrant upwards and level (that is, the face is to be parallel) to the horizon; look through the lower hole of the fore horizon-vane, and if the image of the horizon (or edge of the sea) which you see in the silvered part of the fore horizon-glass, is higher than the horizon itself, which you see on each side
of

of the fore horizon-glass; the horizon-glass leans towards the index-glass. Unscrew the single screw, which is on the fore part of the horizon-glass, and screw up the middle screw, which is at the back of the horizon-glass, till you bring, in one strait line, the image of the horizon, which you see in the silvered part of the horizon-glass, and the horizon itself, which you see on each side of the horizon-glass. When the image of the horizon is lower than the horizon itself, on each side of the horizon-glass, the horizon-glass leans from the index-glass; slack the middle screw, behind the horizon-glass, and screw the single screw that is on the fore side of the glass, till you bring both horizons to make one strait line. Remember, that when this adjustment, as it is called, is once well made, it will seldom want altering, if you mind to leave the screws taut, and nobody has meddled with the screws. However, you ought sometimes to see whether this glass agrees with the index-glass.

To set the Back Horizon-glass upright upon the Face of the Quadrant.

Bring the long line upon the Vernier to lay upon O, upon the arch; hold the face of the quadrant upwards and parallel to the horizon; look thro' the back sight-vane, and, if you use the right eye, put your nose on the left side of the horizon-vane; and if the image of the horizon, in the silvered part of the glass, is higher than the horizon itself, seen through the clear slit in the horizon-glass, the horizon-glass leans forwards; unscrew the single screw on the fore side of the horizon-glass, and screw up the middle screw behind, till you cause the image of the horizon in the silvered part to be brought, as near as possible, into one strait line

with the horizon itself, which you see through the clear slit of the horizon-glass.

If the image of the horizon, in the silvered part of the glass, is lower than the horizon itself, which you see through the clear slit of the glass, the horizon-glass leans backwards; unscrew the middle screw behind the horizon-glass, and screw up the single screw, which is on the fore side of the glass, till you cause both the horizons to make one strait line.

C H A P. VII.

ALL the glasses belonging to the quadrant,

1st, Ought to have no veins.

2dly, They ought to be truly flat on each side.

3dly, Each glass should be of an exact thickness in every place, because these two sides ought to be truly parallel to each other.

The meaning of these three things is, to get one true image of the sun; and if the edges of the image of the sun do not shew to be single and very sharp, the glasses are not good.

To know whether the glasses are good, observe the sun's or the moon's image, when either of them is pretty high, or near 90 degrees; then, if the edges of the sun or of the moon's image shew single, it is a sign the glasses are good.

To measure the Sun's Breadth or Diameter.

Learned men say, that the sun's least breadth or diameter, at one time of the year, is 31 miles and 42 seconds, or sixtieth parts of a mile. At another

ther time of the year, the sun's greatest diameter is 32 miles and 48 seconds. The sum of these two numbers is 64 miles 30 seconds; the half of this 32 miles 15 seconds is called the common diameter; the half of the common diameter is 16 miles and 7 seconds; the 7 seconds are thrown off, and the 16 miles are taken for the sun's half breadth, always in finding the latitude of the ship.

Put the long line upon the Vernier to O, upon the arch; take the quadrant in your right hand, just under the fore sight-vane; put the darker-glass close to the inner side of the fore sight-vane; turn the stem of the dark glasses under the swelling part, upon which the fore sight-vane stands, and turn the other dark glass down upon the side of the quadrant; with your right thumb bear the stem of the dark glasses against the swelling part, whereupon the fore sight-vane stands. Now look through the outer sight-hole in the vane, and thro' the clear part of the horizon-glass, up to the sun, and with your left hand move the index forward, and bring the upper edge of the sun down to touch nicely the sun's lower edge. The Vernier then shews you the sun's breadth or diameter, the half of which is the semidiameter or half breadth.

To find by the Quadrant the Dip of the visible Horizon, below the true Horizon, for any Height of the Eye above the Water.

To understand the meaning of this, you must think the arch is numbered back again from B to Y, with 90 degrees more, and then the quadrant will measure 180 degrees upon the inner arch YB; and it measures also all the degrees upon the outer arch YC, from Y towards C, as far as you have any degrees upon the outer arch. So that now you
are

are to say O is 180 degrees. Then the numbers upon the arch, from Y to B, are to be named in this manner.

90	80	70	60	50	40	30	20	10	0
90	100	110	120	130	140	150	160	170	180
B									Y

Now,

By the back observation, when the long line of the Vernier touches O, which now you are to call 180 degrees, and when your eye is at L [See fig. 2.] and you hold the quadrant upright, it may be said, that the quadrant measures the half circle in the heaven K, B, C, D, and round to Z; and when you push the index beyond 180 degrees (the long line of the Vernier then comes upon the outer arch) till you make the image of the visible horizon, or the point M, behind you (which image of the visible horizon you see in the silvered part of the back horizon-glass) to fall below Z, or the true horizon LZ, down to Y, which is the visible horizon before you. You see you have measured 180 degrees, and also twice the dip; for you have measured the dip or arch MK behind you, and 180 degrees, which is the half circle K, B, C, D, Z, and you have also measured the dip or arch ZY, before you. Now,

Let the long line of the Vernier touch O, which now you are to call 180 degrees. This measures off the half circle K, B, C, D, Z. Look thro' the back sight-vane, and move the index upon the outer arch, till you bring the image of the visible horizon behind you (which is the point M) to make one strait line with the visible horizon before you (which is the point Y.) Then, one half of the miles shewn by the Vernier (on the outer arch) is the dip; and this dip is either the arch MK, or the arch YZ, for the height of the eye at L, above the top of the water at E.

4 00 58

F I N I S.

